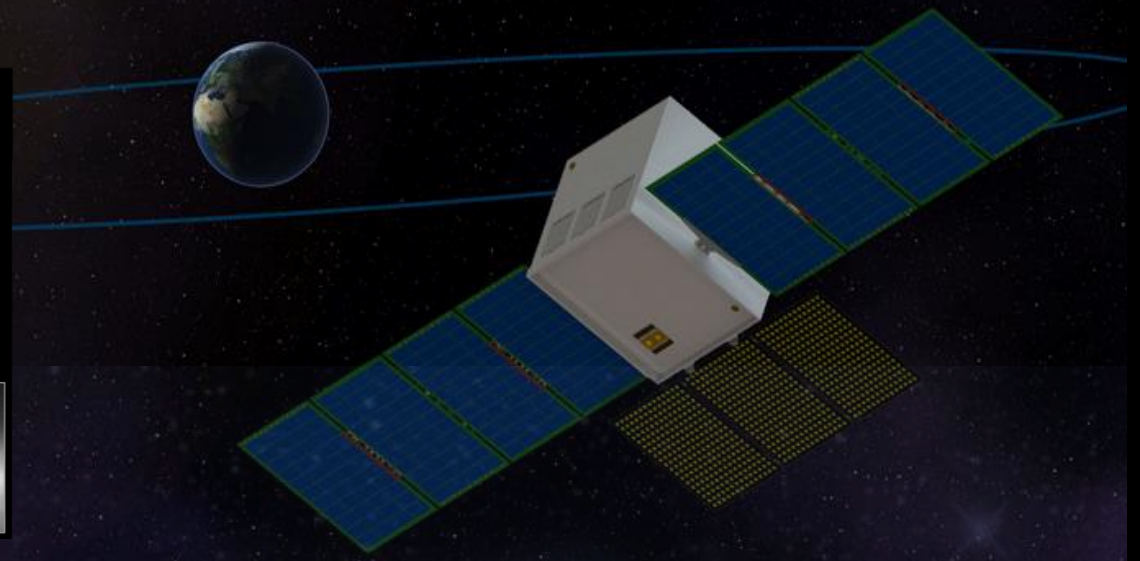
Overview of Primitive Object Volatile Explorer (PrOVE) – Waypoints and Opportunistic Deep Space Missions to Comets

Planetary Science Deep Space SmallSat Study (PSDS3

First flyby of a pristine comet



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INO (Canada) IR Multispectral Camera, MSSS Visible Camera

Why Study Comets?

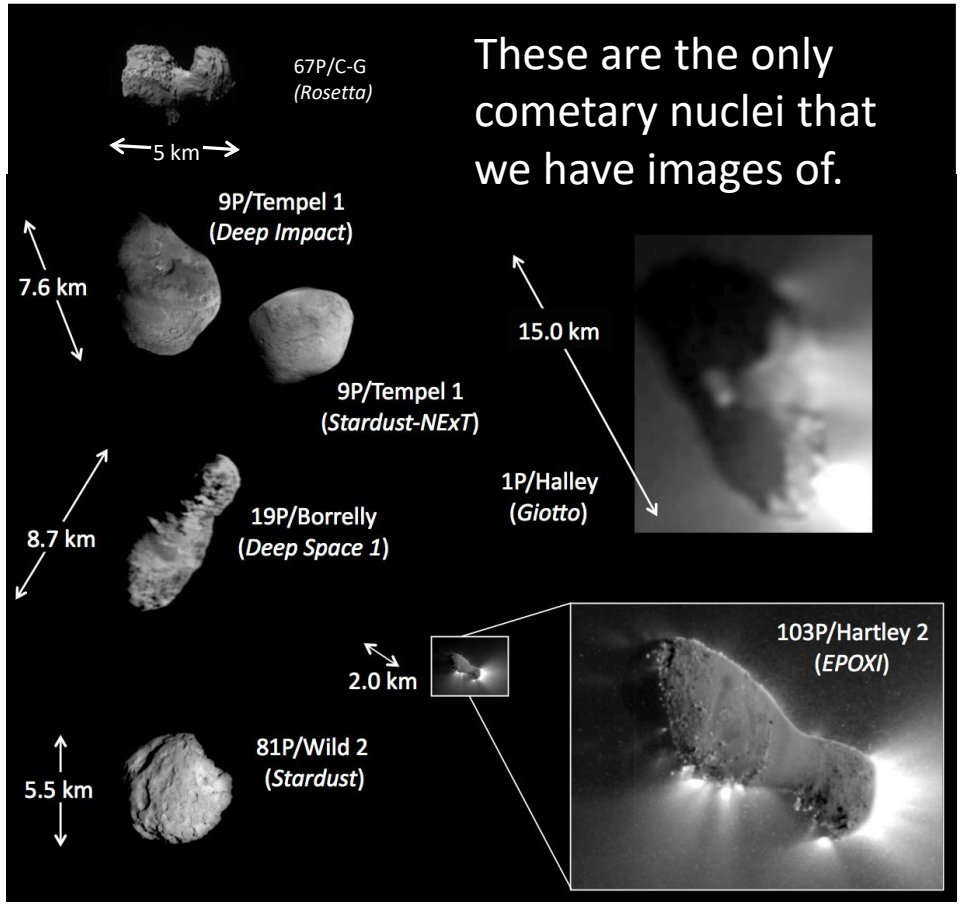
- Are among the most enigmatic and spectacular objects in the sky
  - indelibly recorded throughout human history
- Formed at the beginning of the Solar System (4.6 billion years ago)
  - record conditions, compositional variability, and processes in the protoplanetary disk
  - preserve record of volatiles in the early solar nebula
  - building blocks of the planets
  - bearers of volatiles to inner solar system
- "Stored" in outer Solar System freezer
  - relatively unchanged since formation
- Contain dust, organics, and ices
  - contribute ingredients for life to Earth
- Potentially hazardous to life on Earth

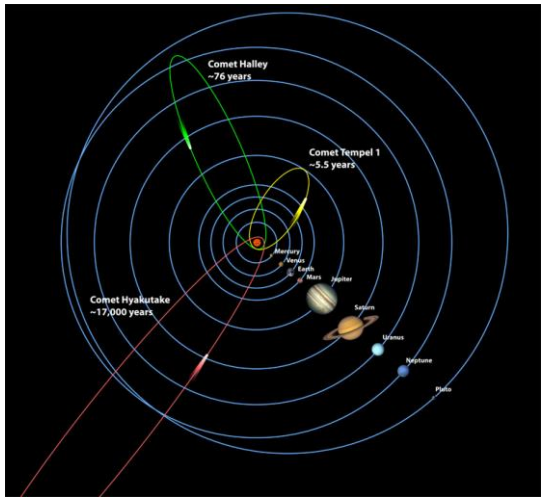
Comet Lovejoy, Dec 2011

Bayeux Tapestry: Battle Hastings 1066

When beggars die, there are no comets seen….
Calpurnia in Shakespeare's Julius Caesar

Types of Comets





- Short period (Jupiter-family)
  - Orbit between Jupiter and the Sun
  - Disturbed by the gravity of the planets
  - Spacecraft have imaged 5
- Halley type (every 50-200 years)
  - Orbit between Pluto and the Sun
  - Spacecraft have imaged 1
- Long period (>> 200 years)
  - "New" and "young" come from the Oort cloud when disturbed by a passing star
  - **None observed up close**

Potential for high science return

Why Waypoints?

New comets:

Hale-Bopp discovery was 2 years prior to perihelion.

Many long-period comets are discovered with even shorter times.

Proposed solution:

Park a spacecraft in space.

Statistics of Oort cloud comets:

Statistics over past 10 years indicate 1 detected every 2 years.

Hughes (2001) estimates the historical long-period comet flux as ~1 per year.

Close flyby to study nucleus of a long-period comet:

Surface maps of ~8-m resolution and volatile inventory will yield compelling scientific results.

The PSDS3 effort showed that a mission to a new comet is within contemporary CubeSat/SmallSat technology!

Primitive Object Volatile Explorer (PrOVE)

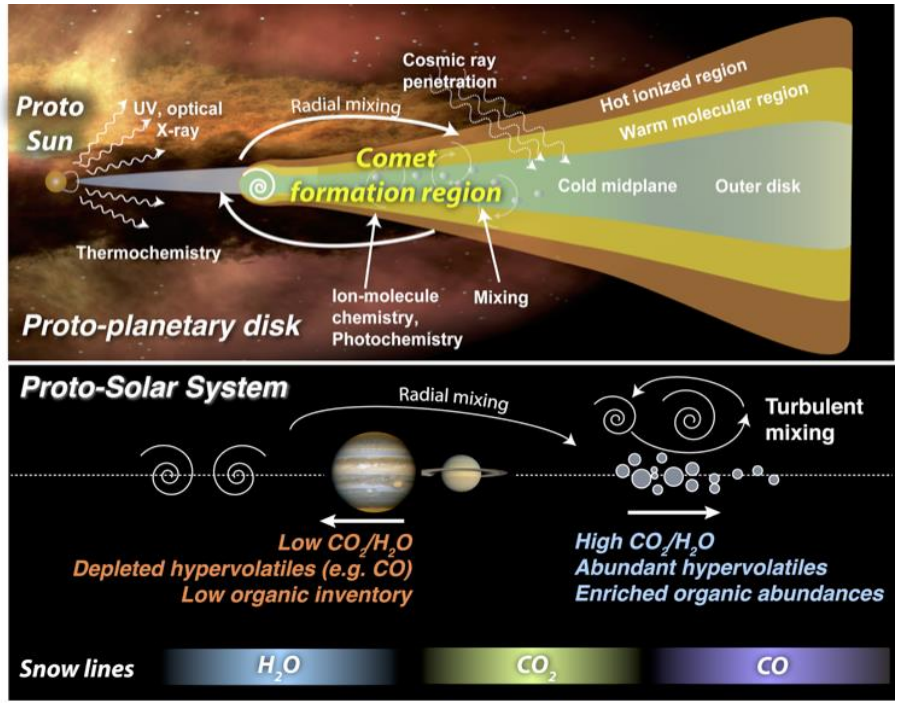
Planetary Science Deep Space SmallSat Studies (PSDS3)

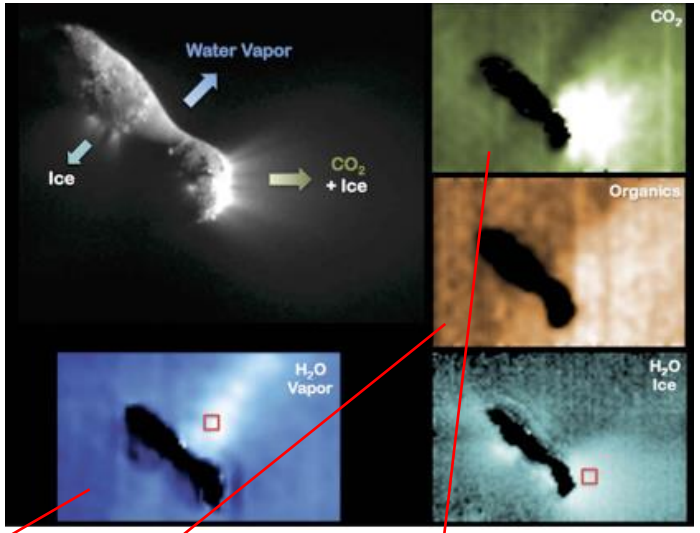
Mission Concept and Science Deliverables

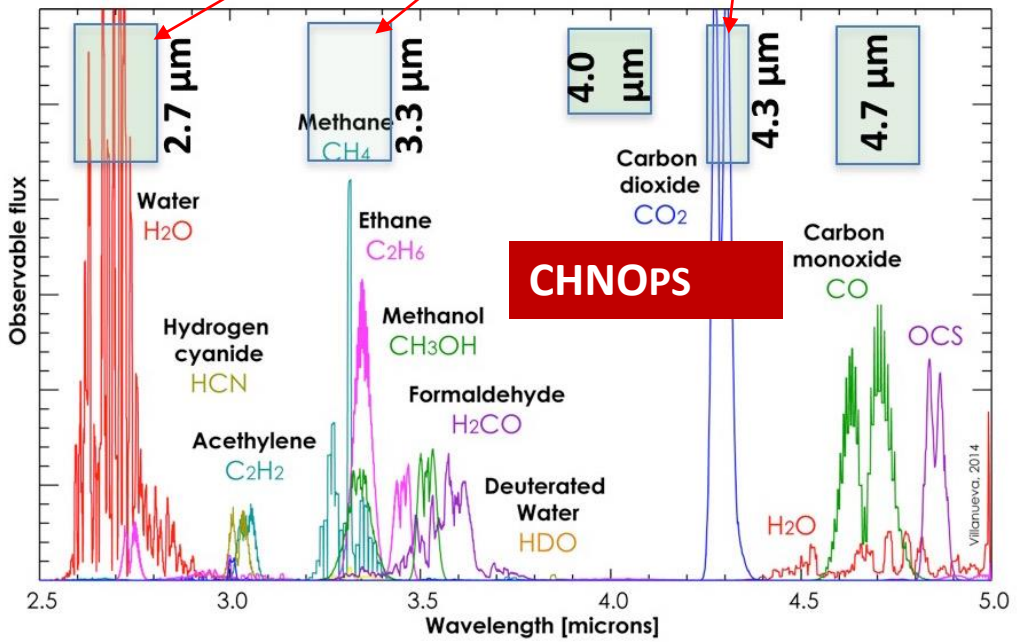
Science Objectives:

PrOVE will perform a close flyby of a *new or Jupiter-family* comet near perihelion when surface processes and volatile activity are maximum, to probe the origin of the nucleus and the formation and evolution of our Solar System.

- *Investigate* morphological and chemical heterogeneity of nucleus by quantifying surface fine structure and volatile species abundances, and how these depend on solar insolation;
- *Map* surface relief and spatial distribution of volatiles, especially CO_2 (which cannot be measured from ground based telescopes), and determine any variations;
- *Determine* the frequency and distribution of outbursts.







PrOVE can address Priority Comet Science!

Ideal Criteria:

Flyby of a dynamically new (Oort cloud) or long period comet. Identify a waypoint/parking orbit in space, launch from an arbitrary platform and disposal above Earth's gravity well, navigate to waypoint with on-board propulsion, indefinite residence with minimal station keeping, design a cruise trajectory to a newly acquired target or a known long period comet, navigate to a new target with on-board propulsion, flyby encounter with 5m optimum spatial resolution (visible imaging).

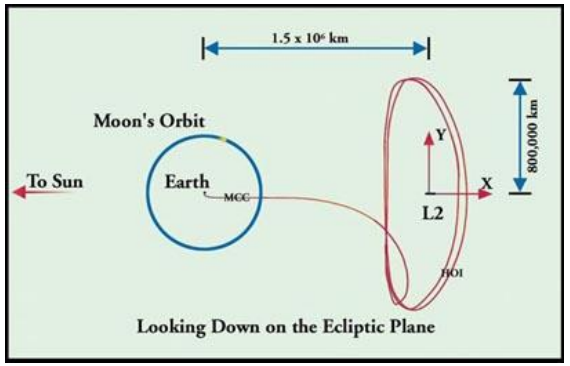
Minimum Criteria:

Flyby of a Jupiter Family comet and Near-Earth comet (q<1.3 AU, P<200 years).

SKG: https://www.nasa.gov/exploration/library/skg.html

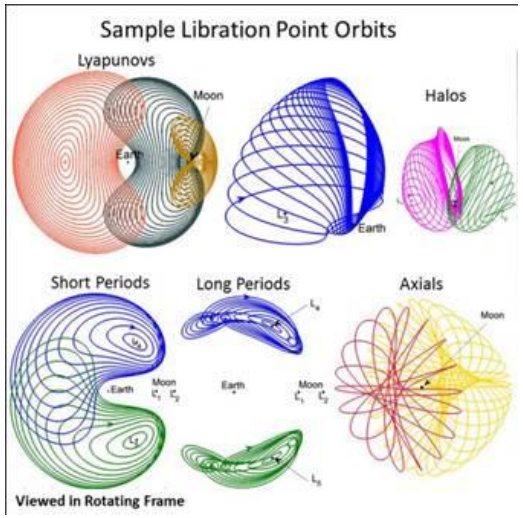
SBAG report on venues/contexts for addressing SKGs "Space-based robotic missions which can be telescopic or precursor mission to a small body target" includes high priority for NEO albedos, size, rotation state, dust environment, resource identification.

Waypoint examples examined in PSDS3



Sun-Earth Libration orbit

Sun-Earth L1/L2 are good solutions
Station keeping is minimal



Other Libration orbit examples

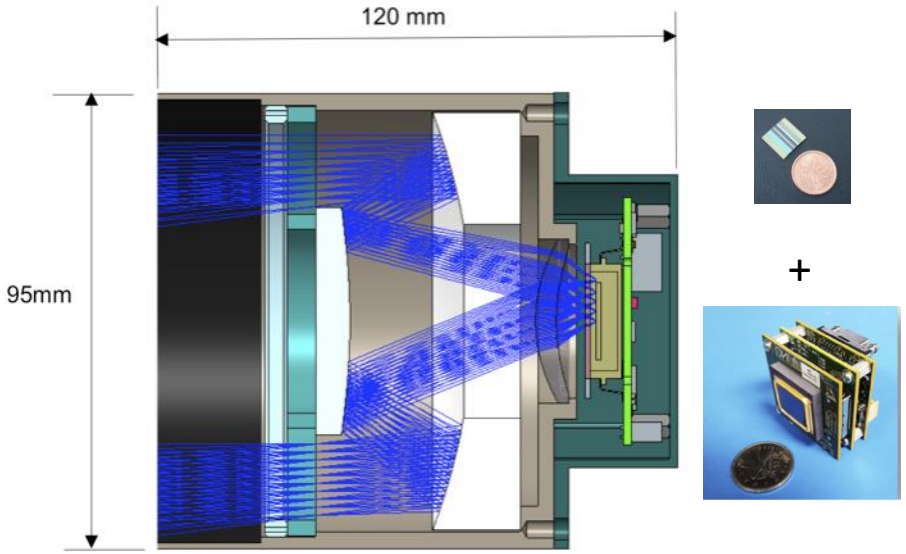
Payloads

Infrared Imager/radiometer

ComCAM: IR microbolometer (with TEC) has broad spectral response (1-100 µm) which includes science requirements of 2-5 µm for molecular species and 8-12 µm for thermal.

- 384x288 pixels
- IFOV = 120 m @300 km
- 1.2 kg, 2.5 W

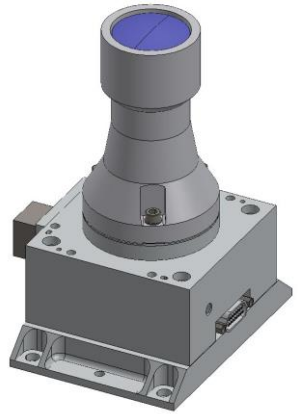
Compact 2-12 µm camera



Visible Imager

VisCAM: High spatial resolution mapping of a Jupiter-family comet surface is optimum. Mapping of a new comet would be unprecedented.

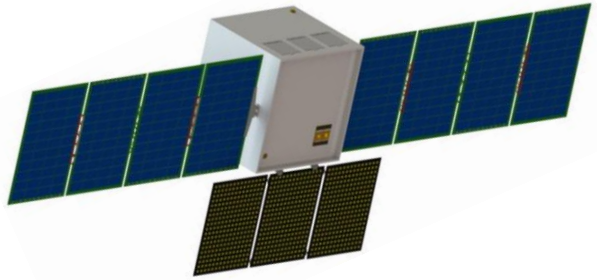
- 2592x1944 pixels
- IFOV= 8 m @ 300 km
- 0.4 kg, -30C<T_{oper}<40C
- 2.5 W imaging, 1.3 W idle



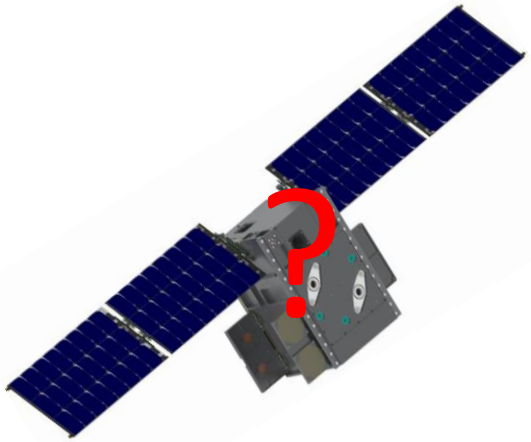
Based on TAGCAMS instrument on OSIRIS—Rex

Spacecraft Concept
ABC/ESPA Bus Assembly

Stowed volume ~100-U or Stowed volume 12U?



ABC/ESPA



e.g., BCT XB12,
MSU 12U bus

Conclusions

- The standard spacecraft/waypoint approach, and the broad spectrum flyby coverage concept presented here has the best chance to produce ground breaking new comet science
- PROVE is within current technological capabilities
- Spacecraft bus: ~100 U initial recommendation, but 12U/24U bus concepts very likely an option, even with 4 year mission lifetime requirement (shielding and ongoing advancement in intrinsically radiation hard electronics architecture and components direction)